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Feathers From Domestic and Wild Fowl

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Feathers have attracted the attention of mankind since earliest times, as shown by remnants found in ancient ruins. Today they are still utilized in many ways. Primitive man adorned himself with showy feathers from wild birds; modern man takes bright feathers from domestic fowl, and conserves the wild birds (*17*).[2] Games such as archery and badminton owe much of their pleasure to precision achieved by the use of common stiff feathers in arrow and shuttlecock. Only a few special feathers are required in dressing artificial flyhooks (*19*), but how the fisherman appreciates them!

There are many practical uses. The feather duster is still available, though goose quills have gone out of style. During the war, large quantities of feathers were suitably dyed and applied to surfaces for camouflage purposes. They were also processed to yield feather fibers, which proved to be acceptable extenders of down for sleeping bags. These fibers will also be used in some of the newer textiles (*20*). But the greatest volume of feathers is used in pillows, quilts, comforters, and upholstery.

It was found during the war that more than 100,000,000 pounds of feathers were largely wasted in this country annually (*18*). This

[1] The authors acknowledge the valuable assistance of the following: Harold W. Wolf for physical measurements and tests of the feathers; Lubow M. Hansen for the bacteriological work; Hazel P. Gump, Francis M. Butler, Molla J. Corson, and Irven Manuel for their help in collecting the details on which the paper is based; and Ethel H. Dolnick, Gladys Carroll, and William H. Evans, Jr., for assistance in the study of the feathers on the birds and their classification into grades.

[2] Numbers in parentheses refer to Literature Cited, p. 27.

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realization led to an investigation of the various types of feathers and their location on different parts of the body, their inherent qualities, their availability, and their preservation. In order to carry out some phases of this investigation, special equipment was designed by the senior author and is illustrated and described in this circular. The work was carried on cooperatively from July 1943 to June 1944 by the Office of the Quartermaster General, United States Army; the Bureau of Animal Industry, United States Department of Agriculture; and the Fish and Wildlife Service, United States Department of the Interior.

In the literature there was found only one comprehensive report of an investigation on feathers from a commercial point of view, namely, by Taut on chicken feathers (*15*).

TYPES OF FEATHERS AND THEIR LOCATION ON THE BODY

The feathers of aquatic birds are more desirable for bedding (including pillows), sleeping bags, and similar purposes than those of other birds. Therefore, in determining the types of feathers found on various parts of the body, one white domestic goose, *Anser anser*, and one white domestic duck, *Anas boschas*, were studied; also one Canada goose, *Branta canadensis*, and one Mallard duck, *Anas platyrhynchos*, since it was thought that possibly supplies could be increased through salvage by hunters of these wild species.

As chickens are raised in this country in enormous numbers, one New Hampshire rooster, one hen, and one broiler, *Gallus domesticus*, were obtained. One pheasant, *Phasianus colchicus*, the comparable bird in the wild, completed the series of birds that were studied in detail.

Feathers do not grow uniformly all over the body of a bird (*13*). Similar kinds of feathers grow on certain areas of the skin, called feather tracts; the other areas are protected by the overlapping of the feathers. These tracts are referred to descriptively as (1) the head tract, (2) the ventral tract, (3) the dorsal tract, (4) the femoral tract, (5) the caudal tract, (6) the scapular tract, and (7) the wing tract.[3] To facilitate the removal of feathers from each tract, the birds were killed by administering lethal doses of nembutal as suggested by Irving Rothchild, in the Animal Husbandry Division of the Bureau. Nembutal apparently eliminates the central nervous system control over the feather-holding mechanism.

Feathers were first described in detail by the ornithologist Nitzsch (*13*) and more recently by Chandler (*2*). For practical purposes, feathers may be divided into two groups, those that are vaned and those that are not vaned (fig. 7). The vane is the flat spreading part on each side of the feather. This vane is made up of filaments called barbs, which in turn bear smaller filaments called barbules. When hooklets are present on the barbules, a means by which all these filaments are held rather firmly together, a vane is formed. If the barbules, however, lack hooklets, the filaments remain loose and form the fluff of a feather. The vaned feathers, which include three-quarters

[3] PIRNIE, MILES DAVID. PLUMAGE CHANGES OF CERTAIN WATER FOWL. Thesis for doctor of philosophy of Cornell University. 1928. (Unpublished).

fluff, half fluff, and saddle and hard feathers, are again subdivided into two groups: narrow-vaned and broad-vaned feathers. The unvaned feathers include the fluff, plumules, and down. Following are the various grades of feathers, as proposed by the authors, with a description of each:

(1) Hard feathers—those with stiff quills, heavy vanes, and a very small amount of fluff; (2) saddle feathers—long, narrow, vaned feathers from the saddle and back of the rooster only; (3) half fluff—vane feathers with fluff along the lower half of the quill; (4) three-quarters fluff—vaned feathers with fluff along the lower three-quarters of the quill; (5) fluff—body feathers with firm shafts bearing only fluff, or the soft part of a feather; (6) plumules—small down feathers with soft shafts, bearing only fluff; (7) down—feathers without a shaft, composed of only a tuft of fluff.

Figure 1.—Body of New Hampshire rooster showing areas covered by different types of feathers. For key to feather areas, see text, pages 3 and 4. (Modified after American Standard of Perfection (*1*).)

The customary appearance of a bird is brought about by the disposition of the various feathers (*1*), as shown in figures 1 to 6, inclusive. Following is the identification of the numbered areas in these figures:

1. Forehead.
2. Crown.
3. Back of head.
4. Cheek.
5. Chin.
6. Throat.
7. Fore part of neck.
8. Side of neck.
9. Hind part of neck.
10. Cape.
11. Chest.
12. Breast.
13. Side.
14. Back.

14A. Sweep of back or saddle.

15. Shoulder.
16. Scapulars.

17. Fluff under wing (on body).
18. Lower thigh.
19. Upper thigh.
20. Belly.
21. Cushion or rump.
22. Rear body.
23. Upper tail coverts.
24. Under tail coverts.
24A. Under tail feathers.
25. Main tail feathers or tail.
26. Hock plumage.
27. Sickle.
28. Thumb of wing.
29 and 29A. Primary wing coverts.
30 and 30A. Wing primaries.
31 and 31A. Lesser wing coverts.
32 and 32A. Middle wing coverts.
33 and 33A. Greater wing coverts.
34. Wing secondaries.
35. Wing axillars.
36. Wing tertials.

The distribution of feathers in chickens is similar in the rooster (fig. 1) and the hen (fig. 2). However, the bright coloring of the

FIGURE 2.—Body of New Hampshire hen showing areas covered by different types of feathers. For key to feather areas, see text. (Modified after American Standard of Perfection (*1*).)

rooster is largely due to the prominent hackle and sickle feathers. The hackle feathers are the specialized neck feathers, and the sickles are the long, curved tail feathers. The feathers of the wings are alike and are therefore shown in figure 3 as chicken wing feathers of the rooster and the hen. In the chicken there is only a small amount of down

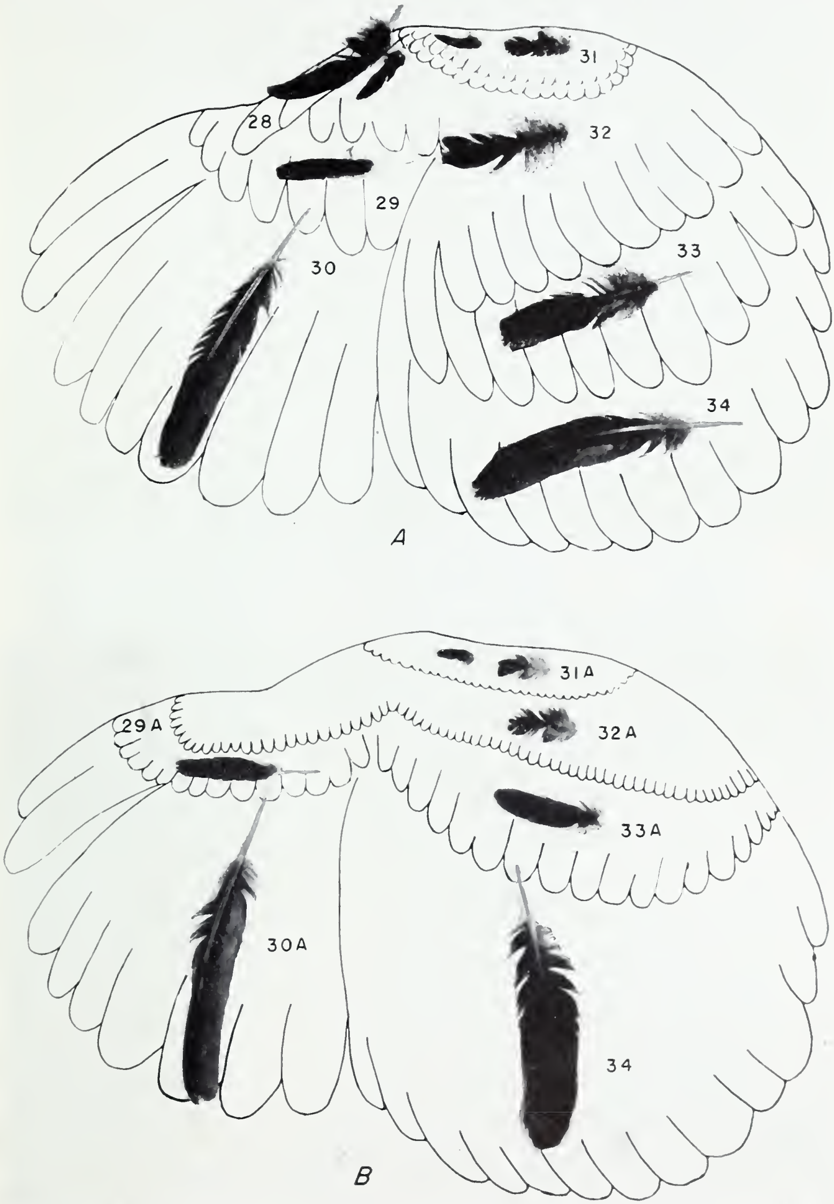

FIGURE 3.—Upper surface (*A*) and lower surface (*B*) of wing of New Hampshire chicken showing areas covered by different types of feathers. For key to feather areas, see text. (Modified after American Standard of Perfection (*1*) and Kortright (*11*).)

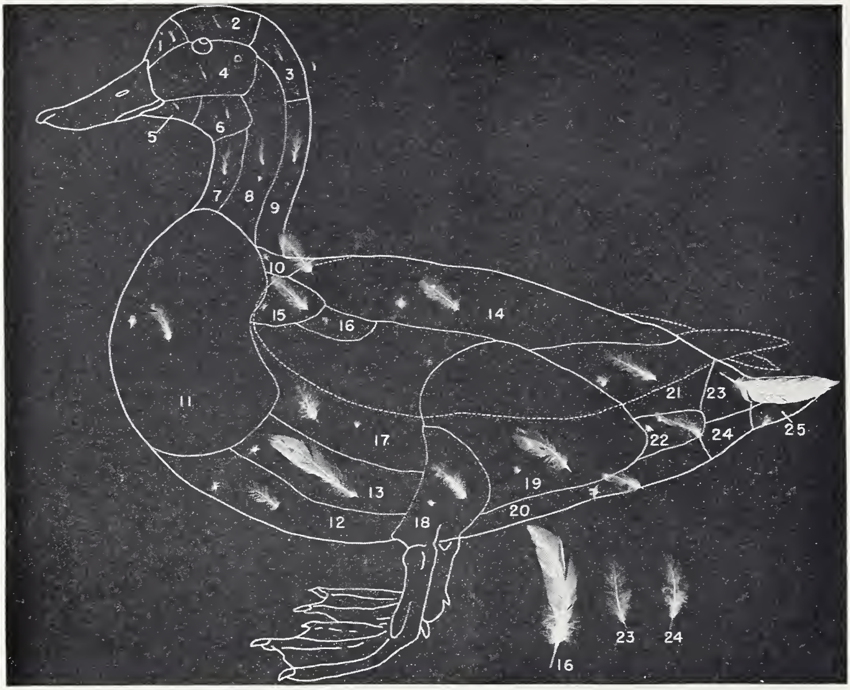

FIGURE 4.—Body of white domestic duck showing areas covered by different types of feathers. For key to feather areas, see text. (Modified after Kortright (*11*).)

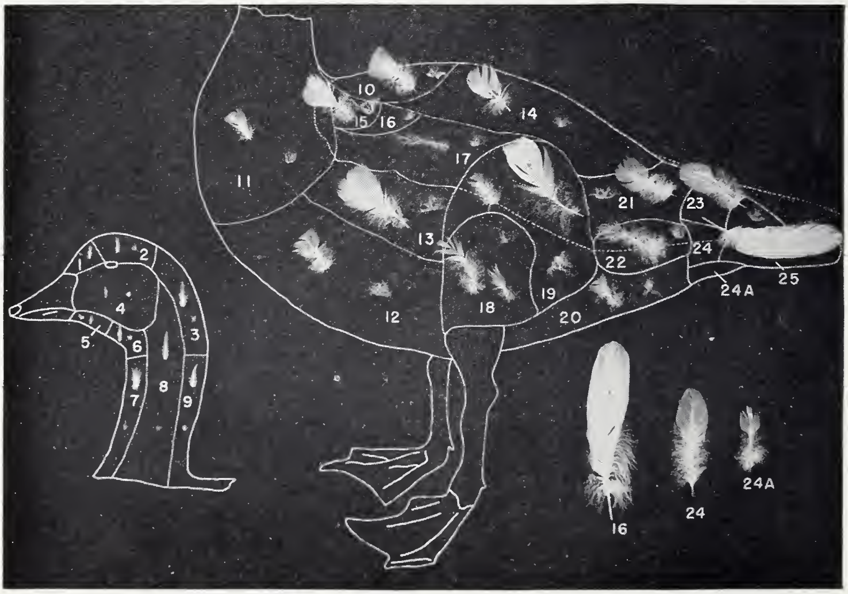

FIGURE 5.—Body of white domestic goose showing areas covered by different types of feathers. For key to feather areas, see text. (Modified after Kortright (*11*).)

and plumules. Fluff is found on the belly and in part of the rear body region; half fluff on the cape, shoulder, back, cushion, lower thigh, breast, and some of the neck feathers; three-quarters fluff in the rear body region, on the upper thigh, and under the tail coverts; and saddle feathers on the saddle, hackle, and back. Head feathers, wing and wing coverts, sickles, main tail feathers, and upper tail coverts comprise the hard feathers. Coverts are the shorter, rather stiff feathers associated with certain long, hard feathers.

The feather areas of the duck (fig. 4) and of the goose (fig. 5) parallel each other and resemble the feather areas of the chicken. Since the types of feathers and their arrangement are similar in the wing of the goose and the duck, only the latter is illustrated (fig. 6). Waterfowl down is particularly desirable on account of its exceptionally high bulking value—the property of filling a considerable space. The figures show that down is present on practically every area of the duck and the goose. The types of feathers on the different areas of these two birds are alike, but the goose feathers give a more

FIGURE 6.—Wing of white domestic duck showing areas covered by different types of feathers. For key to feather areas, see text. (Modified after Kortright (*11*).)

substantial impression owing to their broader vanes, as shown in a comparison of figures 10 and 11.

Plumules are found on the body under the wing and on the rump, thighs, and undersurface of the wings. Fluff occurs in the rear body region. Half fluff is found on the chest, breast, side, shoulder, cape, back, rump, upper and lower thighs, belly, and neck. Three-quarters fluff occurs on the upper thigh and in the rear body region. Hard feathers make up the scapulars, upper and lower tail coverts, all tail

FIGURE 7.—Grades of feathers of the chicken.

feathers, and all wing feathers. The type of feathers known as saddle feathers does not occur in waterfowl. Illustrations of wild fowl are not included since distribution of their feathers was found to be practically the same as that of domestic birds. The main difference between the feathers of wild and domestic birds is coloration (*16*).

A comparison of figures 7 to 11 shows that feathers of the land birds studied are definitely inferior as a filling material to those of the waterfowl. Contrary to general belief, down is present on the chicken (fig. 7), but the amount is so small as to be entirely negligible in the

trade. The quills of the feathers are usually straight and the vanes of the smaller feathers relatively insignificant; consequently, chicken

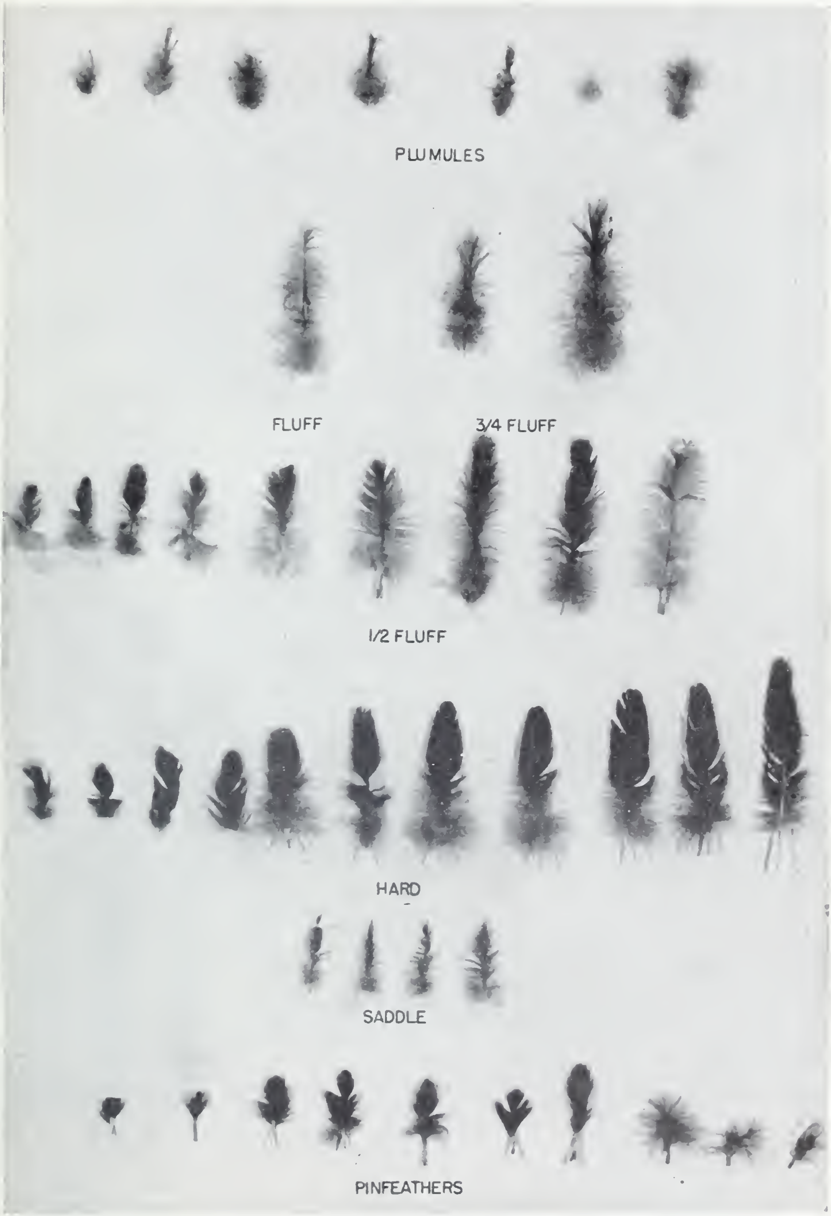

FIGURE 8.—Grades of feathers of the broiler.

feathers have much less bulking value than those of the goose or the duck. Broiler feathers (fig. 8) are even poorer than feathers of adult

chickens; furthermore, they include pinfeathers, whose stiff sheaths have little if any resiliency and make up a considerable proportion of the weight of the feathers. The down and the smaller feathers of the pheasant (fig. 9) are similar in their general structure to those

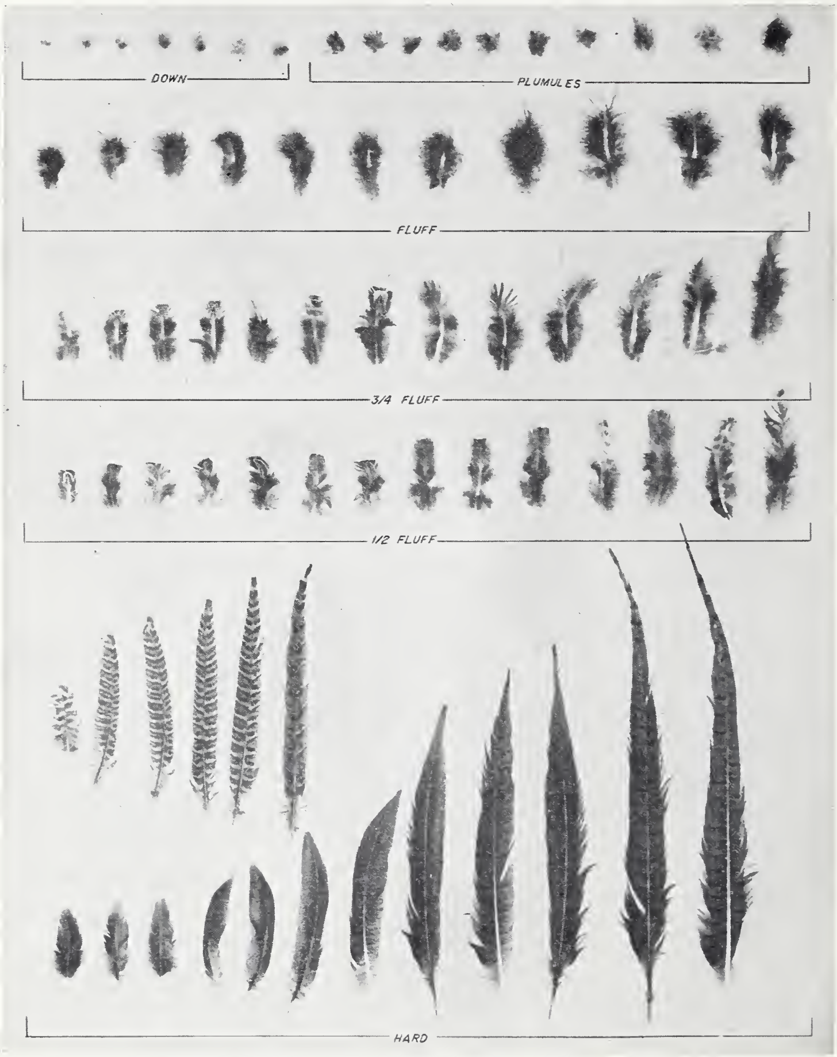

FIGURE 9.—Grades of feathers of the pheasant.

of the chicken. The hard feathers, however, are very much elongated and their beautiful color patterns make them desirable in the millinery trade.

As has already been mentioned, waterfowl down is the most important component of pillows on account of its high bulking value.

On the birds examined, although there was an abundance of down on both the duck and goose, the range in size of the goose down (fig. 10) was much greater than that of the duck down (fig. 11). The smaller vaned feathers (three-quarters fluff and half-fluff) also possess high bulking value. This is, no doubt, in part related to the curvature of the quills of these feathers, goose feathers being even more curved than duck feathers. The size of the vane of goose feathers may also contribute to the bulking value. Duck feathers possess a vane pointed at the tip; the goose feathers have a broad, blunt vane.

The feather trade utilizes feathers of various types and from several kinds of birds, usually in blends, to stuff pillows, comforters (*10*), and sleeping bags and for upholstery purposes. At present, the quality of the products offered the consumer is extremely variable. Practical ways of identifying the contents of pillows and suggestions for the evaluation of their quality have been published by Houtz (*8*). If blends were made on the basis of the physical characteristics of the various types of feathers, two important things would be accomplished. First, the product offered to the consumer would be uniform in quality and could be held to a suitable standard, depending on the purpose for which the product is intended. Secondly, the manufacturer could vary his blends according to the availability of grades of feathers on the market at any given time. By thus making use of the grades of feathers that are abundant, he would probably be able to pass on a saving to the consumer.

SEPARATION OF BULK FEATHERS

Since commercial feathers contain many types, they vary considerably in size. In poultry-dressing plants an effort is made to keep the wing and tail feathers separated from the body feathers. However, in the examination of many samples of bulk commercial chicken feathers, the authors found large wing and tail feathers, broken feathers, and extraneous material. To separate these from the acceptable material, a fractionating tower was designed by the senior author. This tower, constructed of wood, is 9 feet high, 10 inches square, and has four outlets with dampers for closing the outlets, as well as viewing windows through which the flow of feathers can be watched (fig. 12). During periods of low humidity much trouble is experienced with static electricity, and it is important to be able to have a clear vision of the entire tower. Steam is blown into the tower with the feathers to overcome the static electricity when it is first observed that the feathers stick together.

The tower is equipped with a variable-speed blower capable of seven different operating speeds for blowing the feathers upward from the bottom of the tower. Since all feathers have a given terminal velocity according to size when falling, the regulation of the air current within the tower can be adjusted to lift the small, fluffy feathers so that they will blow out of the top outlet and allow other larger, less fluffy feathers to drop to the bottom of the tower. The feathers, depending on their size, are successively blown through outlets 1, 2, 3, and 4, only one outlet being open at a time. Feathers that do not blow as high as outlet 4 are the residue, consisting of coarse material and

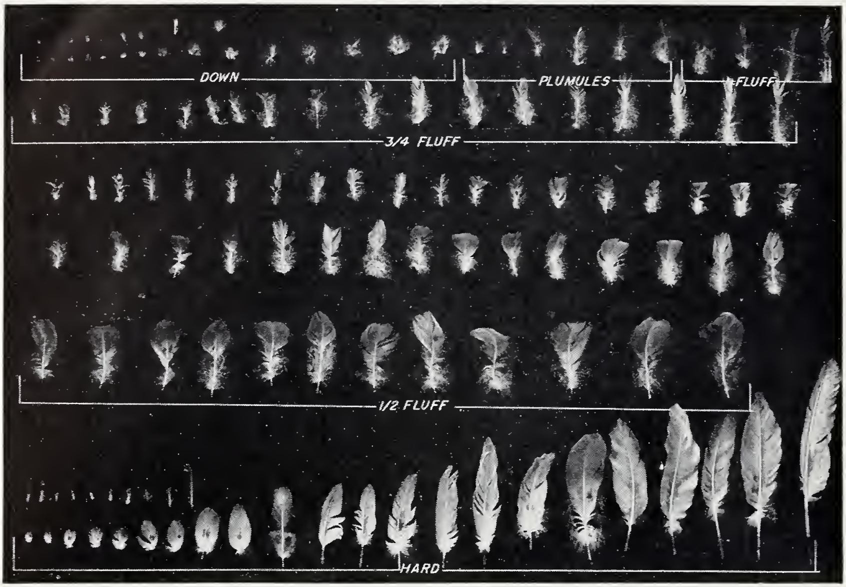

FIGURE 10.—Grades of feathers of the domestic white goose.

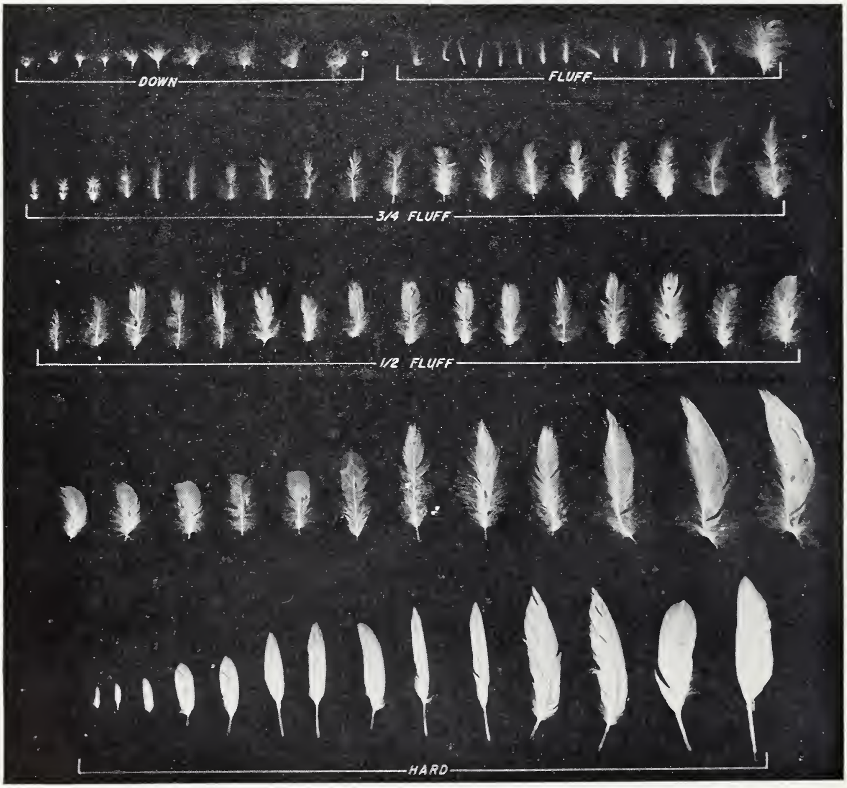

FIGURE 11.—Grades of feathers of the domestic white duck.

Figure 12.—Fractionating tower for separating bulk feathers into different sizes or grades.

quills. The type of feathers coming from outlet 4 can sometimes be felt in commercial feather pillows. The removal of these greatly improves the feather mixture. To make a good pillow, there should be a blend of the types of feathers passing through outlets 1, 2, and 3.

The tower has been found to work well for freeing down from other feathers, for separating waterfowl and chicken feathers into the various grades, and for blending down and other feathers in different combinations by the recirculation of weighed portions. Through the use of the tower it was possible to obtain some samples of chicken feathers having properties closely resembling waterfowl feathers. It

was also possible to obtain reliable information on the content of down in mixtures of down and other waterfowl feathers.

Table 1 shows the results obtained in the separation of chicken feathers by means of the tower. In comparison with the older birds

TABLE 1.—*Analysis on a weight-percentage basis, of chicken feathers, by means of the fractionating tower*

Fractionating tower outlet No.[1]	Feather group passing through outlet	Rhode Island Red cockerels	Plymouth Rock broilers	New Hampshire broilers	Hens of mixed breeds
		Percent	*Percent*	*Percent*	*Percent*
1	Very light	12. 2	21. 7	23. 1	13. 5
2	Medium light	38. 5	25. 9	15. 4	35. 7
3	Medium heavy	45. 3	32. 6	28. 8	47. 8
4	Very heavy	3. 9	19. 8	32. 7	2. 9

[1] Tower outlets are numbered from the highest to the lowest.

for which feather analyses were made, the broilers had a high proportion of very light, fluffy feathers. They also had a high proportion of very heavy feathers, which consisted largely of pinfeathers.

RESILIENCY OF FEATHERS

An important property of a filling material is the occupation of a relatively large volume for its weight and the recovery to that volume after compression. Waterfowl down meets this requirement in that it may be compressed under load to a small volume and it recovers to its approximate original volume when the pressure is released. As stated earlier, the property that feathers have of filling a considerable space is commonly called the bulking value.

The realization that the quality of a filling material depends on both ease of compressibility and recovery to the original volume led the senior author to try to develop a method that could measure both of these properties quickly and accurately. In 1938 he found that the reversing of the carriage of an I–P–2 Scott inclined-plane tester (fig. 13) gave good results. Prior to this time, there was no satisfactory method of evaluating the resiliency of filling materials. Most of the early work was confined to the measurement of the bulking value, which is merely an indication of the volume a material will assume. Hardy (*7*) described a compression method for measuring the volume of clean wool. This was later expanded by Johnston (*9*). Robinson (*14*), using a machine that applied a fixed load, studied the resiliency of a number of common vegetable-fiber fillers.

With the reversing of the carriage of the I–P–2 Scott tester and the use of a cylindrical container, good reproducible results on similar samples of the same material are obtained. The inside diameter of the cylinder measures 3.84 inches, and the contents are compressed under a load of 100 gm. per square inch. The machine is also so constructed that it can be made to subject material to repeated loading and unloading; the results are recorded automatically on a chart.

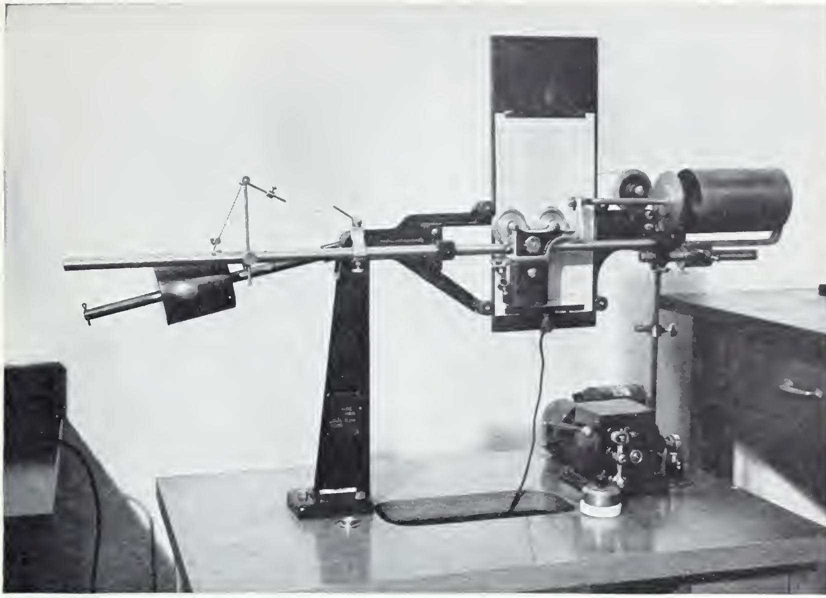

FIGURE 13.—I–P–2 Scott inclined-plane tester: carriage reversed for measuring resiliency of feathers.

Ordinarily the test is conducted as follows: 20 gm. of the material is confined in a wire-mesh basket for 4 hours in a room maintained at a temperature of 70° F. and 65 percent relative humidity. The sample is then transferred to a cylinder mounted upon the inclined-plane tester. This transfer is best accomplished by loosening the thumbscrew below the cylinder and putting the cylinder upon the workbench in a vertical position. After the sample is placed in the cylinder, the latter is replaced on the tester and the plunger is set so that a recording pen is at zero on the chart, shown in figure 13. When the machine is put in motion, the long shaft is mechanically lowered at its right end. The only pressure upon the feathers is that of the carriage assembly sliding down against them. A recording pen makes a curve upon the chart (fig. 14) as it crosses, and the chart is mechanically lowered at a fixed rate of speed. When the pen is near the top of the chart, the gear mechanism automatically reverses and the pen comes back toward the zero position. This process represents one cycle in the machine's operation. In a perfectly resilient material, such as an elastic band, the pen will come back to zero for the first few cycles. Most materials will become less resilient after each cycle. The third cycle was adopted as the most satisfactory one in the work with feathers.

Figure 14 is a record, on the chart, for a sample of raw goose down tested with this machine. After the third cycle, the compressed thickness (X) of the sample, under a load of 100 gm. per square inch, was 2.95 inches (table 3), and the recovered thickness (Y) was 3.69 inches. These measurements have a direct relation to the bulking value, which is 42.73 cubic inches. The distance through which the compressed sample expands upon the release of the load is known as

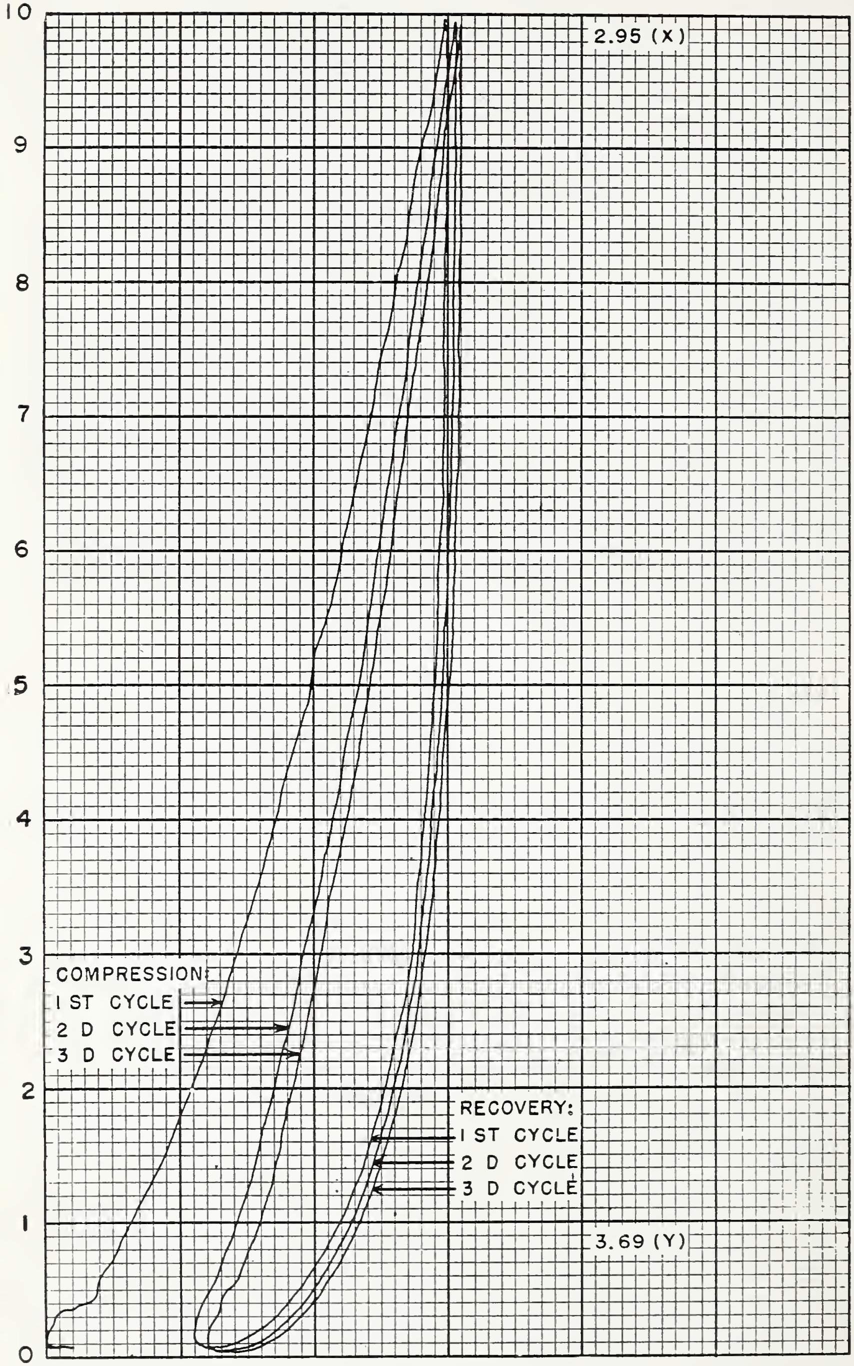

FIGURE 14.—Chart record of the movement of the carriage of the inclined-plane tester in determining the compressed thickness (X) and recovered thickness (Y) of a sample of raw goose down.

the difference, or the *d* value, and also as the resiliency. The higher this *d* value, the greater is the desirability of the feathers as a filling material.

Table 2 shows the compressional data obtained by means of the inclined-plane tester on various kinds of commercial feathers from different sources.

TABLE 2.—*Compressional data on some feathers*

Material	Length of feathers	Runs	Compressed thickness (X) (at 100-gm. pressure per square inch)	Recovered thickness (Y) (at 1/10 maximum pressure)	Difference between Y and X (d)	Bulking value
	Inches	*Number*	*Inches*	*Inches*	*Inches*	*Cubic inches*
Waterfowl down		1	3. 08	3. 78	0. 70	43. 772
Raw goose down		1	2. 95	3. 69	. 74	42. 730
Goose breast feathers		1	2. 53	2. 92	. 39	33. 814
Raw goose feathers		3	2. 37	2. 79	. 42	32. 308
Duck feathers		3	2. 05	2. 39	. 34	27. 700
40/60 mixture		2	2. 26	2. 91	. 65	33. 698
Fowl feather (mixed)		3	1. 52	1. 73	. 21	20. 033
Curled chicken feathers			1. 80	2. 25	. 44	26. 055
Chicken—						
Down and plumules	0–2	1	1. 16	1. 32	. 16	15. 286
Do	2–3	1	1. 20	1. 36	. 16	15. 749
Fluff	2–3	1	1. 42	1. 62	. 20	18. 760
Do	3–4	1	1. 65	1. 85	. 20	21. 423
Do	4–5	1	2. 40	2. 54	. 14	29. 413
¾ fluff	3–4	1	1. 97	2. 17	. 20	25. 129
Do	4–5	1	2. 11	2. 28	. 17	26. 402
½ fluff	2–3	1	1. 85	2. 16	. 31	25. 013
Do	3–4	1	2. 03	2. 24	. 21	25. 939
Saddle feathers	2–3	1	1. 59	1. 82	. 23	21. 076
Do	3–4	1	1. 85	1. 95	. 10	22. 581
Do	4–5	1	2. 09	2. 25	. 16	26. 055
Hackle feathers	4–5	1	1. 93	2. 05	. 12	23. 739
Vaned feathers	0–2	1	1. 38	1. 72	. 34	19. 918

Goose feathers are usually superior to duck feathers, as shown in table 2. Chicken feathers were found to be inferior to waterfowl feathers in bulking value. As the length of any grade of feathers increased, the bulking value also increased. Furthermore, as the proportion of fluff on the feathers increased, the bulking value increased. The removal of vaned feathers raised the bulking value appreciably. Other treatments of feathers that raised their bulking value included the washing and fluffing of feathers while drying. Likewise, the curling of feathers greatly improved them in this respect. In the feather industry, curling results from passing the feathers between two heavy metal plates. These plates have intermeshing-shaped teeth adjustable for fine or coarse curling. The experienced feather processor is able to adjust these plates for most efficient curling.

DURABILITY OF FEATHERS

Durability is an important property of feathers. Most feathers appear to withstand normal use and can be fluffed back to practically their original state.

An apparatus to test durability by pounding was developed by the senior author as an adaptation of the old-fashioned windlass. A 30-gm. sample of feathers, contained in a 6- by 6- by 2-inch pad, was

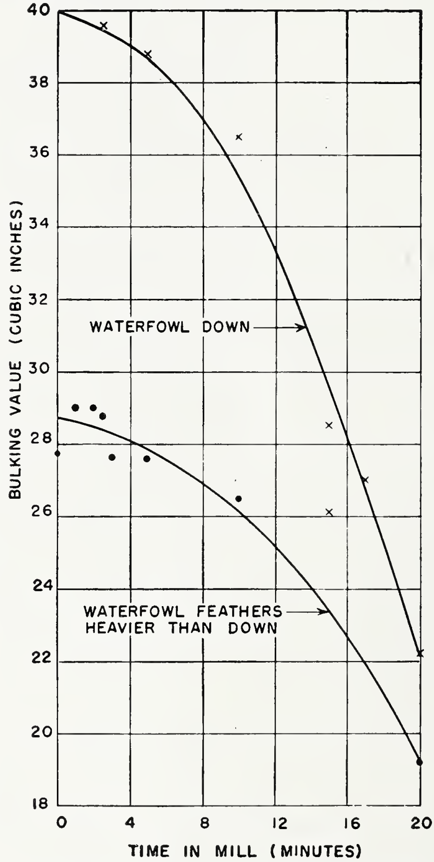

Figure 15.—Relation between time in ball mill and bulking value of waterfowl down and heavier feathers.

pounded by a 23-pound plunger dropping 6 inches on the pad. Down and also the standard 40/60 mixture were found to be extremely resistant to this treatment. After being pounded, the feathers were compacted; refluffing usually was sufficient to restore them to practically their original state. Generally the material could stand 100,000 impacts without apparent damage.

It was then decided that action would have to be more severe in order to obtain a measure of the durability of the feathers. The grinding action by a ball mill gave the desired wear, and the degree of damage could be controlled by altering a number of factors. The

extent of mechanical degradation may be controlled by making the following factors constant: Size of sample, weight and size of grinding pebbles, speed of mill, and time of grinding.

In tests conducted with waterfowl down and other feathers, 25 gm. of material was ground in a 1-gallon mill with 6¾ pounds of flint pebbles. The mill was operated at a speed of 68 r. p. m., and the samples were milled for various lengths of time with resulting wide range in damage. After only 20 minutes of grinding, the down and other feathers appeared greatly altered—in many ways resembling second-hand materials. The reduction in bulking value with increased periods of milling is shown in figure 15 for waterfowl down and heavier feathers. In the latter, the midrib (rachis), however, was extremely resistant and remained unaltered after extended milling. It was possible, by increasing the grinding to a period of hours, to convert the entire material—both down and other feathers—into a fine powder. This method has given more concrete data on the resistance of feathers to mechanical action than any other method known. It also offers possibilities as a practical durability test on feathers for consumer use. Feathers embrittled by washing, bacterial action, or age respond to ball milling more rapidly than similar feathers not so embrittled.

CLEANLINESS OF FEATHERS

To ascertain the amount of fine particles and dust in feather samples, particularly second-hand materials, even after the feathers are washed,

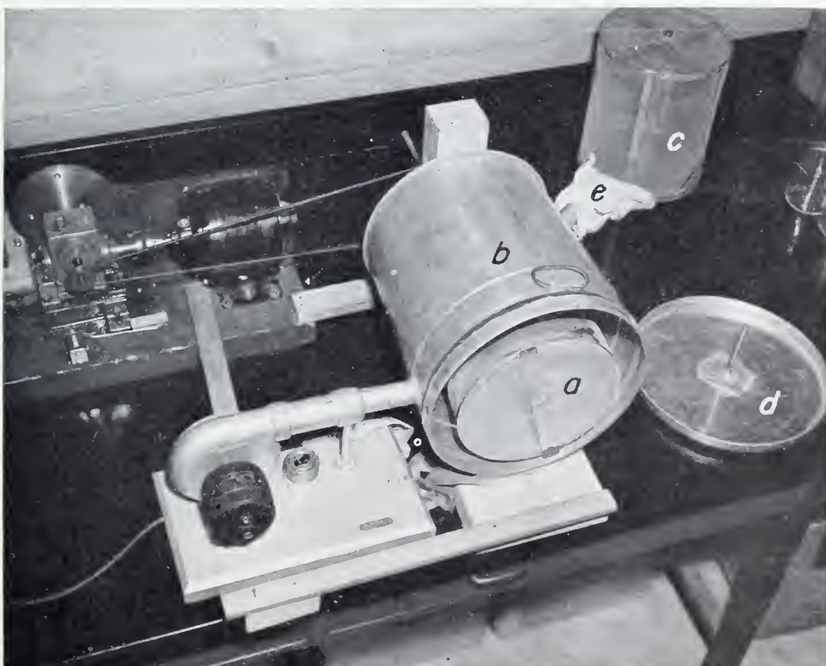

Figure 16.—Apparatus for separating fine particles and dust remaining in washed feathers: *a*, Wire-mesh drier and duster; *b*, metal container of drier and duster; *c*, wire-mesh cylinder in which feathers are washed; *d*, lid for container *b*; *e*, bag in which dust is collected.

a rotating wire-mesh drier and duster (fig. 16, *a*), large enough to hold a 30-gm. sample and inclosed in a metal container, *b*, was designed and built by the senior author.

The feathers are washed in a wire-mesh cylinder, *c*, in a solution made from a mild soap and a small quantity of a wetting agent (a chemical that wets the feathers more readily than does water). They are then rinsed in clear water and, to remove the excess water, placed in a centrifuge container similar to the one in which the feathers were washed. To remove the remainder of the dust and complete the drying process, the feathers are transferred to the wire-mesh basket, *a;* the lid, *d*, is placed on the outer metal container, *b;* and the wire basket caused to rotate slowly while air is blown through the system. The fine particles are collected in a bag, *e*, attached to the outlet. The feathers are dried by warm air blown tangentially against the slowly revolving sample. The complete drying and dusting operation is accomplished in approximately 30 to 45 minutes.

The results obtained by the use of the drier and duster with various kinds of feathers from different commercial sources are shown in table 3. The feather designations given in this table are those used by the concerns supplying the feathers. As shown by the table, used materials have a high content of dust and other particles. The loss in shrinkage of these materials as a result of the cleaning procedure ranged from 18 to 48 percent. Even in one of the so-called new materials—curled chicken feathers—the loss in shrinkage was approximately 20 percent. Results similar to these may be accomplished when old feather pillows are sent to the cleaner for renovation. Feather pillows are often used for many years without cleaning; in some cases, for generations. Few other household products are required to undergo such prolonged use without cleaning.

TABLE 3.—*Results obtained with the rotating drier and duster in cleaning various types of feathers*

(Weight of each sample before washing and dusting—30 gm.)

Material	Weight after washing and dusting	Weight of residue recovered	Total loss in weight	Loss in shrinkage
	Grams	*Grams*	*Grams*	*Percent*
New:				
China duck down	27.0	1.3	3.0	10.0
China duck feathers	27.4	.9	2.6	8.8
Standard 40/60	28.3	.1	1.6	5.3
Curled chicken feathers	24.1	4.3	5.9	19.7
Used:				
Good used down	23.1	5.6	6.9	23.1
Do	24.6	2.9	5.4	18.0
Good used feathers	24.4	2.3	5.6	18.7
Good used waterfowl feathers	21.6	1.2	8.5	28.2
Poor used down	23.6	5.2	6.4	21.3
Do	15.3	9.3	14.7	48.0
Poor used feathers	23.3	5.2	6.8	22.5
Poor used waterfowl feathers	22.9	4.6	7.6	25.2

In cleaning comparatively large quantities of feathers, they were washed and rinsed in a manner similar to that described above and squeezed free from excess water by the use of an ordinary wringer. Wrapping the feathers in cheesecloth facilitated the handling of them. When chicken feathers had developed a bad odor, they were given a preliminary cleaning by immersing them in Stoddard solvent (a high-flash-point gasoline) and drying them. The regular washing procedure was then followed.

The difficulty of drying and fluffing the feathers was overcome by the use of a wire cylinder (fig. 17), built by the senior author. This

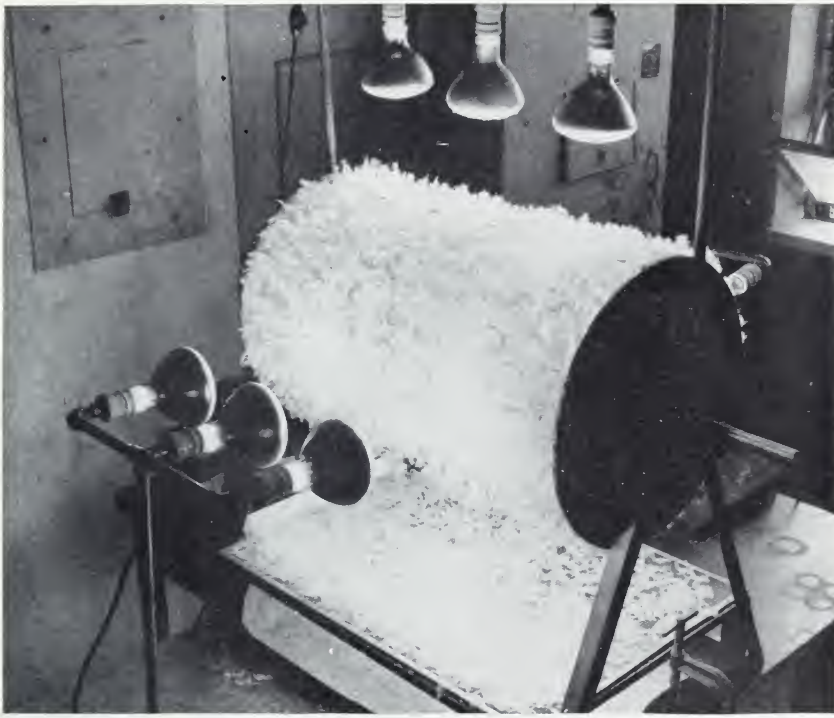

Figure 17.—Radiant drier for drying and fluffing feathers.

cylinder is made to revolve slowly by the use of an electric motor while being heated by three banks of three infrared drying lamps. A screen is placed below the apparatus to free the feathers from any small particles that might drop from the cylinder while the feathers are being dried. Excellent results in drying and fluffing are obtained with this drier, although some labor is required to pick up the feathers after they are dried and fluffed. After complete drying, the feathers are then well agitated and mixed by blowing through the fractionating tower.

APPLYING BACTERIOLOGICAL AND CHEMICAL TESTS

Bacteriological and chemical tests were developed and applied to determine the types of micro-organisms that cause decomposition in

feathers and also to determine the products of decomposition. In making the first bacteriological tests the following plating procedure was used: 5 gm. of feathers was weighed out aseptically and transferred to a 1-liter flask with 500 cc. of sterile water. The suspended feathers were shaken vigorously and 1 cc. of the liquid pipetted into each of a number of sterile Petri dishes in various dilutions (1:100, 1:1,000, 1:10,000, 1:100,000, 1:1,000,000, and 1:10,000,000). About 25 cc. of neutral to slightly alkaline melted gelatin was poured over each dish, which was carefully agitated to insure equal distribution of the organisms present. The gelatin was then allowed to solidify. The plates were incubated at about 20° C. for 2 to 5 days, after which counts of the total numbers and of the liquefying organisms were made. In these tests, feathers were normally found to harbor organisms of the colon type usually caused by bits of manure. Besides these, liquefiers, which also indicate decomposition, occurred with great regularity.

Experiments carried out with various samples of feathers have indicated that the presence of ammonia is associated with high total

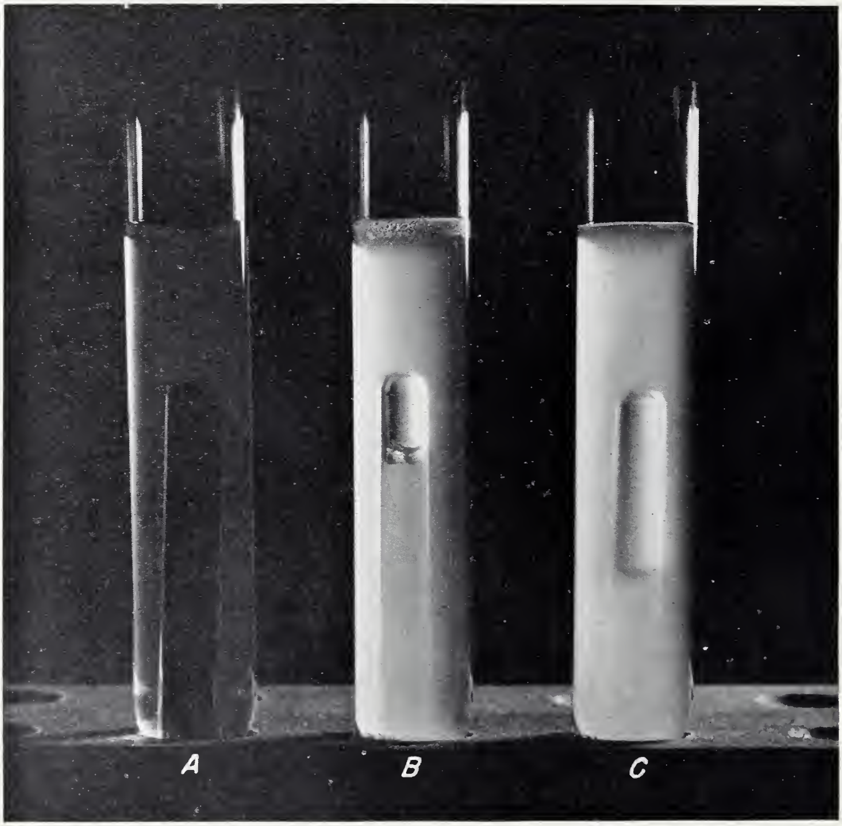

FIGURE 18.—Effect, on gas formation in lactose media, of liquid from clean and dirty feathers: *A*, no gas formation from clean feathers; *B*, medium degree of gas formation from moderately dirty feathers; *C*, high degree of gas formation from very dirty feathers.

counts of micro-organisms, with high counts of liquefying bacteria, and a great number of organisms capable of producing gas in lactose media (fig. 18). The liquid from clean feathers or dilutions of 1:100 fail to produce gas from lactose at 37° C., whereas the liquid from dirty feathers do so in dilutions as low as 1:1,000,000. In periods of high humidity, such gas sometimes forms in dirty feathers, resulting in bad odors. A gram of clean feathers may carry a few liquefiers, but a gram of dirty feathers will carry millions and the liquid from such feathers completely liquefy plates within 2 days.

Any method requiring the incubation of feather cultures is far too time-consuming for a practical test for bacterial contamination when many samples must be examined in a limited time. However, as a referee test, such a procedure might prove valuable.

The suitability of a colorimetric ammonia determination has been tested on various feather samples. This is the test described by Hansen (*4, 5, 6*) and was chosen because it does away with distillation, is simple of execution, requires no special equipment, and enables one to obtain accurate quantitative results within a few hours.

Briefly, the procedure is as follows: A definite amount of feathers is transferred aseptically to a jar with a measured amount of sterile water. After vigorous shaking, the feathers are allowed to soak at room temperature for 1 or more hours, and 5 cc. of the liquid is pipetted out into each of a number of test tubes. Then 1 cc. of thymolate solution and 1 cc. of hypobromite are added, and the tubes are agitated to facilitate the color reaction which takes place in the presence of ammonia. Depending on the concentration of ammonia, the reaction appears light green to blue green or bluish in the aqueous phase. After 20 minutes of standing, 3 or 5 cc. of ether is added to shake out the color in the upper layer. Dissolved in ether, the reacting material appears faint yellow, pink, or pink to deep purplish red, depending on the amount of ammonia present. By matching the colors with standards prepared with definite amounts of ammonia, the amount of soluble ammonia in a sample is determined within 3 hours with a sensitivity as much as 1 mg. per liter.

Dozens of ammonia tests were carried out at first to ascertain whether the distilled water and substrates used might not also give the reaction and upset or complicate the results. Feathers and cultures grown directly from the feather samples were then tested for ammonia content. These tests were accompanied by platings for obtaining data on the types and numbers of bacteria present. The growth of the organisms from the cultures with decomposed feathers is readily seen in figure 19; for the clean feathers no growth was obtained.

Tests were made on a number of stains as to their suitability in detecting differences between relatively clean and unclean feathers, and commercial feathers graded satisfactory and unsatisfactory. It was found that the more stain a feather absorbed the greater the number of bacteria that it contained. Fast green, Congo red, and cotton blue proved to be satisfactory.

The importance of cleanliness of feathers has been recognized by 36 States and the District of Columbia to such an extent that they have passed laws on sanitation requirements for new bedding and upholstery. These laws apply to feathers when used in mattresses,

FIGURE 19.—Culture from decomposed feathers showing considerable growth of bacteria.

comforters, quilts, quiltings, pads, cushions, pillows, upholstered furniture in general, and certain specified types of furniture such as lounges and sofas. The laws are summarized by Mermin and Mayer (*12*). The sterilization of bedding and upholstery materials has been described by Dooley (*3*).

PRESERVATION OF FEATHERS

Most chicken feathers gathered in this country are plucked wet and decompose rapidly if not dried immediately. During the earlier stages of decomposition, the only noticeable effect may be development of noxious odors, but later the feathers may become disintegrated and entirely worthless as filling material. Owing to the acute shortage of filling materials during the war, tests with feathers were made to determine the value of a number of different preservative solutions, including mineral and organic acids, salt, formaldehyde, phenolic compounds, and various proprietary mixtures. Adequate preservation under certain conditions was obtained by using salicylic and benzoic acid. However, these chemicals were costly compared with the value of the material being preserved.

A simple and inexpensive treatment was developed (*18*) in which 15 pounds of common salt and a pint of commercial concentrated hydrochloric acid were dissolved in 30 gallons of water for each 15 pounds of wet feathers to be preserved. After the solution was mixed thoroughly, the feathers were added and allowed to stand overnight. They could then be shipped in gunny sacks to the feather-processing plant.

Bacteriological tests substantiated in general the practical tests. The treated feathers were low in liquefying organisms and coliforming bacteria, as shown in table 4. Moreover, the chemical tests indicated a low ammonia content. The use of a fresh preservative resulted in the formation of considerably fewer liquefiers than the use of a preservative for the second or third time. This result was obtained regardless of whether the feathers were tested in the wet or dry state. Furthermore, feathers tested when dry had fewer of the organisms than those tested when wet. The washed and dried feathers had good resiliency and were comparable in appearance and odor with feathers that had been processed immediately after plucking.

SUMMARY

The realization that enormous quantities of feathers, the byproduct of the poultry business and of hunters' bags, are wasted led to the investigation of the various types of feathers and their location on different parts of the body, their inherent qualities, their availability, and their preservation. To carry on some phases of this work, special equipment was designed by the senior author and is illustrated and described in this circular. The work was carried on cooperatively from July 1943 to June 1944 by the Office of the Quartermaster General, United States Army; the Bureau of Animal Industry, United States Department of Agriculture; and the Fish and Wildlife Service, United States Department of the Interior.

The types of feathers and their location on the body were studied by plucking the following domestic birds: White goose, white duck, New Hampshire rooster, hen, and broiler. The following wild birds also were plucked: Canada goose, Mallard duck, and pheasant. The feathers of each bird were classified, according to structure and size, into two main groups—vaned feathers and unvaned feathers—and then into the following proposed series of grades: Hard feathers, saddle feathers, half fluff, three-quarters fluff, fluff, plumules, and down.

The feathers of the land birds studied were found to be definitely inferior as a filling material to those of the waterfowl. Waterfowl down is particularly desirable on account of its exceptionally high bulking value. The types of feathers on the different areas of the duck and goose are alike, but goose feathers have the greater bulking value owing to their broader vanes. Down was found on the chicken, but the amount was very small. The quills of chicken feathers are usually straight and the vanes of the smaller feathers relatively insignificant; consequently their bulking value is comparatively low. Broiler feathers are even poorer than feathers of adult chickens.

TABLE 4.—*Results of chemical and bacteriological tests on chicken feathers treated with common salt and hydrochloric acid at Moberly, Mo., and shipped to Beltsville, Md.*

Condition of preservative	Method of handling feathers after treatment and shipping	State of feathers tested	Ammonia content	Liquefiers per gram of feathers	Hydrogen ion concentration (pH)
			Percent	*Number*	
Fresh	Not washed	Wet	<0.01	300	3.5
Used second time	do	do	<.01	5,000	4.1
Used third time	do	do	<.01	1,000	6.2
Fresh	Washed	Dry	<.01	100	3.5
Used second time	do	do	<.01	700	4.3
Used third time	do	do	<.01	800	6.4

A fractionating tower has been developed in which, by blowing air currents at variable speeds, down can be freed from other feathers, and feathers can be separated into the various grades and also blended.

Resiliency of feathers was measured through the use of a modified Scott I–P–2 inclined-plane tester. Goose feathers were found to be superior to duck feathers, which in turn were superior to chicken feathers.

An apparatus to test durability by pounding was developed. Since feathers were found to stand 100,000 impacts without apparent damage, more severe action was applied to them by grinding them in a ball mill. In 20 minutes, the down and other feathers were greatly altered—in many ways resembling second-hand materials.

To remove fine particles of dust associated with feather samples, a small rotating drier and duster was designed and built. In samples of used product cleaned by this method, the loss in weight ranged from 18 to 48 percent.

Feathers were washed usually with a mild soap in a small quantity of wetting agent, sometimes with a pretreatment in a high-flash-point gasoline. To overcome the difficulty of drying and fluffing the feathers, a drier was devised, consisting of a wire cylinder caused to revolve slowly by an electric motor while being heated by three banks of three infrared drying lamps. The results of bacteriological and chemical tests showed the importance of properly cleaning feathers before using them.

Wet-plucked feathers in quantity were adequately preserved by a new, simple, inexpensive method, whereby the wet feathers are soaked overnight in a solution consisting of 15 pounds of common salt, 1 pint of hydrochloric acid, and 30 gallons of water for each 15 pounds of wet feathers.

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